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EPA Office of Compliance Sector Notebook Project

Profile of the Non-Metal, Non-Fuel Mining Industry

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Office of Compliance
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency
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This report is one in a series of volumes published by the U.S. Environmental Protection Agency (EPA) to provide information of general interest regarding environmental issues associated with specific industrial sectors. The documents were developed under contract by Abt Associates (Cambridge, MA), and Booz-Allen & Hamilton, Inc. (McLean, VA). This publication may be purchased from the Superintendent of Documents, U.S. Government Printing Office. A listing of available Sector Notebooks and document numbers is included at the end of this document.

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Electronic versions of all Sector Notebooks are available on the EPA Enviroene Bulletin Board and via Internet on the Enviro$ense World Wide Web. Downloading procedures are described in Appendix A of this document.

All photographs by Steve Delaney, EPA. Photographs courtesy of Luck Stone Corporation, Leesburg, Virginia. Special thanks to John_LeGore.

Contacts for Available Sector Notebooks

The Sector Notebooks were developed by the EPA Office of Compliance. Particular questions regarding the Sector Notebook Project in general can be directed to the EPA Work Assignment Managers:

Michael Barrette	Gregory Waldrip
US EPA Office of Compliance	US EPA Office of Compliance
401 M St., SW (2223-A)	401 M St., SW (2223-A)
Washington, DC 20460	Washington, DC 20460
(202) 564-7019	(202) 564-7024

Questions and comments regarding the individual documents can be directed to the appropriate specialists listed below.

Document Number	Industry	Contact	Phone (202)
EPA/310-R-95-001.	Dry Cleaning Industry	Joyce Chandler	564-7073
EPA/310-R-95-002.	Electronics and Computer Industry	Steve Hoover	564-7007
EPA/310-R-95-003.	Wood Furniture and Fixtures Industry	Bob Marshall	564-7021
EPA/310-R-95-004.	Inorganic Chemical Industry	Walter DeRieux	564-7067
EPA/310-R-95-005.	Iron and Steel Industry	Maria Malave	564-7027
EPA/310-R-95-006.	Lumber and Wood Products Industry	Seth Heminway	564-7017
EPA/310-R-95-007.	Fabricated Metal Products Industry	Greg Waldrip	564-7024
EPA/310-R-95-008.	Metal Mining Industry	Keith Brown	564-7124
EPA/310-R-95-009.	Motor Vehicle Assembly Industry	Suzanne Childress	564-7018
EPA/310-R-95-010.	Nonferrous Metals Industry	Jane Engert	564-5021
EPA/310-R-95-011.	Non-Fuel, Non-Metal Mining Industry	Keith Brown	564-7124
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EPA/310-R-95-013.	Petroleum Refining Industry	Tom Ripp	564-7003
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EPA/310-R-95-015.	Pulp and Paper Industry	Maria Eisemann	564-7016
EPA/310-R-95-016.	Rubber and Plastic Industry	Maria Malave	564-7027
EPA/310-R-95-017.	Stone, Clay, Glass and Concrete Industry	Scott Throwe	564-7013
EPA/310-R-95-018.	Transportation Equipment Cleaning Industry	Virginia Lathrop	564-7057

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LIST OF ACRONYMS

AFS - AIRS Facility Subsystem (CAA database)
AIRS - Aerometric Information Retrieval System (CAA database)
AMD - Acid Mine Drainage
ARD - Acid Rock Drainage
BIFs - Boilers and Industrial Furnaces (RCRA)
BOD - Biochemical Oxygen Demand
CAA - Clean Air Act
CAAA - Clean Air Act Amendments of 1990
CERCLA - Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS - CERCLA Information System
CFCs - Chlorofluorocarbons
CO - Carbon Monoxide
COD - Chemical Oxygen Demand
CSI - Common Sense Initiative
CWA - Clean Water Act
D&B - Dun and Bradstreet Marketing Index
ELP - Environmental Leadership Program
EPA - United States Environmental Protection Agency
EPCRA Emergency Planning and Community Right-to-Know Act
FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act
FINDS - Facility Indexing System
f.o.b.- Free On Board or Freight On Board
HAPs - Hazardous Air Pollutants (CAA)
HSDB - Hazardous Substances Data Bank
IDEA - Integrated Data for Enforcement Analysis
LDR - Land Disposal Restrictions (RCRA)
LEPCs - Local Emergency Planning Committees
MACT - Maximum Achievable Control Technology (CAA)
MCLGs - Maximum Contaminant Level Goals
MCLs - Maximum Contaminant Levels
MEK - Methyl Ethyl Ketone
MSDSs - Material Safety Data Sheets
NAAQS - National Ambient Air Quality Standards (CAA)
NAFTA - North American Free Trade Agreement
NCDB - National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
NEIC - National Enforcement Investigation Center
NESHAP - National Emission Standards for Hazardous Air Pollutants
NO2 - Nitrogen Dioxide
NOV - Notice of Violation

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LIST OF ACRONYMS (CONT'D)

NO_X - Nitrogen Oxide
NPDES - National Pollution Discharge Elimination System (CWA)
NPL - National Priorities List
NRC - National Response Center
NSPS - New Source Performance Standards (CAA)
OAR - Office of Air and Radiation
OECA - Office of Enforcement and Compliance Assurance
OPA - Oil Pollution Act
OPPTS - Office of Prevention, Pesticides, and Toxic Substances
OSHA - Occupational Safety and Health Administration
OSW - Office of Solid Waste
OSWER - Office of Solid Waste and Emergency Response
OW - Office of Water
P2 - Pollution Prevention
PCS - Permit Compliance System (CWA Database)
POTW - Publicly Owned Treatments Works
RCRA - Resource Conservation and Recovery Act
RCRIS - RCRA Information System
SARA - Superfund Amendments and Reauthorization Act
SDWA - Safe Drinking Water Act
SEPs - Supplementary Environmental Projects
SERCs - State Emergency Response Commissions
SIC - Standard Industrial Classification
SO_2 - Sulfur Dioxide
SX/EW - Solvent Extraction/Electrowinning
TOC - Total Organic Carbon
TRI - Toxic Release Inventory
TRIS - Toxic Release Inventory System
TRIS - Toxic Chemical Release Inventory System
TSCA - Toxic Substances Control Act
TSS - Total Suspended Solids
UIC - Underground Injection Control (SDWA)
UST - Underground Storage Tanks (RCRA)
VOCs - Volatile Organic Compounds

NON-FUEL, NON-METAL MINING
(SIC 14)

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water, and land pollution are an inevitable and logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education/outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water, and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial "sector-based" approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, States, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community, and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate, and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene Bulletin Board or the Enviroene World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing these data systems. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the existing notebooks reflect an approximation of the relative national occurrence of facility types that occur within each sector. In many instances, industries within specific geographic regions or States may have unique characteristics that are not fully captured in these profiles. For this reason, the Office of Compliance encourages State and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested States may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with State and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume.

If you are interested in assisting in the development of new notebooks for sectors not covered in the original eighteen, please contact the Office of Compliance at 202-564-2395.

Because this profile was not intended to be a stand-alone document concerning the non-fuel, non-metal mining industry, appended is a full reference of additional EPA documents and reports on this subject, as listed in the March edition of the Federal Register.

II. INTRODUCTION TO THE NON-FUEL , NON-METAL MINING INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the non-fuel, non-metal mining industry. The type of facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes. Additionally, this section contains a list of the largest companies in terms of production.

II.A. Introduction, Background and Scope of the Notebook

This profile provides an overview of SIC code 14, which includes mining and quarrying of nonmetallic minerals, except fuels; and establishments engaged primarily in mining or quarrying, developing mines, or exploring for non-fuel, nonmetallic minerals. Also included are certain well and brine operations, and primary preparation plants engaged in crushing, grinding, and washing.

Mining is defined simply as the taking of minerals from the earth. Minerals can be classified as either fuel minerals or non-fuel minerals. Non-fuel minerals can be further divided into metallic and nonmetallic minerals. This industrial profile is concerned only with the mining and quarrying of non-fuel, nonmetallic minerals, although many of the mining activities and processes involved are very similar to those performed in mining metallic minerals. Quarrying is an open-pit mining process designed specifically for the removal of either dimension stone or crushed stone by the cutting and loosening of blocks or blasting.

Establishments engaged primarily in crushing, pulverizing, or otherwise treating non-metal minerals are classified as mining facilities, whether or not they operate in conjunction with mines. However, if the crushing, pulverizing, or other treating activities take place off-site, the establishments are classified under SIC 3295 and are not addressed by this profile.

SIC 14 categorizes the industry according to the types of minerals mined. The following list indicates the three-digit SIC codes used to further distinguish the types of minerals within the industry, and their associated end uses:

SIC 141 - Dimension Stone/End Uses: Construction
SIC 142 - Crushed and Broken Stone, Including Riprap/End Uses: Construction
SIC 144 - Sand and Gravel/End Uses: Construction, Lime Manufacturing
SIC 145 - Clay, Ceramic, and Refractory Minerals/End Uses: Bricks, Cement and Paper
SIC 147 - Chemical and Fertilizer Mineral Mining/End Uses: Glass,

Soaps, and Fertilizer
SIC 148 - Nonmetallic Minerals Services, Except Fuels
SIC 149 - Miscellaneous Nonmetallic Minerals, Except Fuels/End Uses: Insulation, Textiles, and Abrasives.

Separate profiles have been developed for the metal mining, and stone, clay, glass, and concrete products industries.

II.B. Characterization of the Non-Metal, Non-Fuel Mining Industry

The industry covered in this profile comprises establishments engaged in mining or quarrying, developing mines, or exploring for non-fuel, nonmetallic minerals such as dimension stone; crushed and broken stone; sand and gravel; clay, ceramic, and refractory minerals; chemical and fertilizer minerals, and other miscellaneous non-fuel, nonmetallic minerals. Also included under this SIC code are primary preparation plants, such as those engaged in crushing, grinding, or washing non-fuel, nonmetallic minerals. This section of the profile provides information on industry size and geographic distribution, product characterization, and economic trends. The predominant industries in this SIC code are crushed stone and sand and gravel. This section of the profile concentrates heavily on these two industries.

II.B.1. Industry Size and Geographic Distribution [1]

Crushed Stone Producers

A total freight on board (f.o.b.) of 1.1 billion metric tons of crushed stone, valued at $5.9 billion was reported produced in the United States in 1993 by 1,566 companies with 3,213 operations and 3,915 active quarries through open-pit mining. (See Section III.A. for a discussion of mining processes.) Most of the crushed stone produced in 1993 came from operations with an annual output greater than 300,000 tons; 1,182 operations, representing 37 percent of the total, produced 84 percent of the total tonnage.

In 1993 the ten top producing states, in descending order of tonnage were Texas, Pennsylvania, Florida, Illinois, Missouri, Ohio, Virginia, Georgia, Kentucky, North Carolina, accounting for 51 percent of the total domestic output.

Exhibit 1 lists the ten leading companies that produce crushed stone in the United

States. These ten companies, with a total of 507 active operations and 509 quarries, account for 31 percent of the total output of crushed stone in the United States.

Exhibit 1

(In terms of total output of crushed stone)

Company	**Number of Active Operations**	**States**
1. Vulcan Materials Company	158	Alabama, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia, Wisconsin
2. Beazer USA, Inc./Hanson PLC	98	Alabama, Arizona, California, Georgia, Indiana, Kentucky, Michigan, New Mexico, New York, North Carolina, Ohio, Oregon, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington
3. Martin Marietta Aggregates	130	Georgia, Indiana, Iowa, Kansas, Maryland, Missouri, Nebraska, North Carolina, Ohio, South Carolina, Virginia, Wisconsin
4. CSR America, Inc.	24	Florida, Georgia, Indiana, Ohio, South Carolina

Source: Directory of Principal Crushed Stone Producers in the United States in 1993, U.S. Department of the Interior, Bureau of Mines.

Exhibit 1 (cont'd)
Leading Crushed Stone Producers
(In terms of total output of crushed stone)

Company		Number of Active Operations	States
5	Rogers Group Inc.	27	Alabama, Indiana, Kentucky, Ohio, Tennessee, Virginia
6.	Lafarge Corporation	20	Illinois, Iowa, Kansas, Kentucky, Michigan, Missouri, New York, Ohio, Pennsylvania, Texas
7.	Florida Rock Industries, Inc.	18	Florida, Georgia, Maryland, Virginia
8.	Tarmac America, Inc.	11	Florida, South Carolina, Texas, Virginia
9.	Dravo Corporation	11	Alabama, Florida, Illinois, Kentucky, Louisiana, Ohio
10.	Lone Star Industries, Inc.	12	California, Illinois, Indiana, Missouri, New York, Oklahoma, Oregon, Pennsylvania, Texas

Source: Directory of Principal Crushed Stone Producers in the United States in 1993, U.S. Department of the Interior, Bureau of Mines

A total of 93 underground mines produced 65.2 million metric tons of crushed stone in 1993, as opposed to 1.1 billion metric tons produced from open-pit mining. Underground mines were located in 20 states. The leading states in descending order of tonnage were Kentucky, Iowa, Illinois, Missouri, Indiana, Maryland, and Tennessee. Their production represented 76 percent of the total U.S. crushed stone produced from underground mines.

Sand and Gravel Producers

A total of 919 (834 million short tons) of construction sand and gravel valued at 3.3 billion, f.o.b. plant, was reported produced in 1992 by 4,213 companies with 5,999 operations. Some companies produced both construction and industrial sand and gravel from the same operations. In 1992, most of the sand and gravel came from operations that produced more than 200,000 tons per year; 1,290 operations, representing 22 percent of the total, produced 71 percent of the total tonnage.

Exhibit 2 lists the ten leading companies that produce sand and gravel in the United States.

Exhibit 2
10 Leading Companies in Order of Total Output of Sand and Gravel

Company		Number of Active Operations	States
1.	Calmat Co.	28	Arizona, California, New Mexico
2.	Beazer USA, Inc./Hanson PLC	43	Arkansas, California, Georgia, Indiana, Louisiana, Nevada, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Texas, Washington
3.	CSR America Inc.	39n	Arizona, Georgia, Florida, Indiana, Michigan, Nevada, Ohio, South Carolina, Washington
4.	Ashland Oil, Inc./APAC, Inc.	41	Alabama, Arizona, Arkansas, Florida, Georgia, Mississippi, Oklahoma, North Carolina, South Carolina
5.	Redland PLC	38	Colorado, Kansas, Maryland, New Mexico, Texas
6.	Dravo Corporation	17	Alabama, Florida, Ohio, Pennsylvania, West Virginia
7.	Vulcan Materials Co.	22	Alabama, Florida, Illinois, Indiana, Iowa, Tennessee, Texas, Wisconsin
8.	Lonestar Industries, Inc.	8	California
9.	Pioneer Concrete of America	10	Pennsylvania, Texas
10.	Lafarge Corp.	19	Louisiana, Missouri, New York, Ohio, Pennsylvania, Texas, Washington, West_Virginia

Source: Directory of Principal Sand and Gravel Producers in the United States in 1992, U.S. Department of the Interior, Bureau of Mines.

Exhibit 3
Geographic Distribution of the Industry

II.B.2. Product Characterization

Crushed stone and sand and gravel are the two main sources of natural aggregate. Both are used in almost all residential, commercial, and industrial buildings, and in most public works projects such as roads and highways, bridges, railroads, dams, airports, water and sewer systems, and tunnels. Together, crushed stone and sand and gravel make up approximately half the volume of mined minerals in the United States.

Crushed stone and sand and gravel are widely used commodities that are important elements in many national industries. Sand and gravel (or sand alone) can be used for industrial purposes such as foundry operations, in glass manufacturing, as an abrasive, and in filtration beds of water-treatment facilities. Crushed stone is used as a source of calcium for fertilizers, as a metallurgic fluxstone, and as the major resource in the manufacture of cement and lime. It is also used in water and sewer filtration systems and in the manufacture of glass.

Crushed stone and sand and gravel, however, are most commonly used as aggregate in the construction industry. As an example, an average 1,500-square-foot home requires approximately 114 tons of aggregate. If you add each home's proportional share of new streets, schools, churches, municipal projects, and shopping centers, the total aggregate use per home increases to approximately 328 tons (Shumway and Silva, 1993).

Many types of non-fuel, nonmetallic minerals comprise this industry. The major SIC groups of non-fuel, nonmetallic minerals and some of the minerals within each group include: dimension stone (mica schist, granite, limestone, marble, sandstone, slate), crushed and broken stone (limestone, granite, dolomite, cement rock, sandstone, trap rock), sand and gravel (industrial sand, construction sand, gravel, pebble, silica, abrasive sand), clay, ceramic, and refractory minerals (kaolin, ball clay, fire clay, china clay, paper clay, kyanite), chemical and fertilizer minerals (potassium compounds, boron compounds, sodium compounds, phosphate rock, sulfur), and miscellaneous nonmetallic minerals (asbestos, diatomite, gypsum, asphalt rock, graphite, precious stones). Some of the more commonly mined non-fuel, nonmetallic minerals include crushed and broken stone (limestone), sand and gravel (silica sand), and clay (kaolin clay). Non-fuel, nonmetallic minerals are also referred to as industrial minerals.

II.B.3. Economic Trends

According to a Bureau of Mines Study, the demand for crushed stone in 1994 was expected to be about 1.17 billion metric tons (1.29 billion short tons), a 5 percent increase compared with that of 1993. Gradual increases in demand for construction aggregates have occurred after 1994, based on increased volume of work on the infrastructure that is being financed by the Intermodal Surface Transportation Efficiency Act of 1991 and is the result of the recovery of the U.S. economy. The law authorized $151 billion to be spent in the next 6 years on transportation projects, of which $119.5 billion was allocated for highway work and $32.5 billion for mass transit.

It was estimated that the demand for crushed stone will reach 1.3 billion tons in 1995 although the final numbers for 1995 have not been released. The projected increases will be influenced by construction activity primarily in the public as well as the private sector.

Crushed stone f.o.b. prices are not expected to increase significantly, even if the demand for construction aggregates will rise over the forecasts. However, the delivered prices of crushed stone are expected to increase, especially in and near metropolitan areas, mainly because more aggregates are transported from distant sources.

The demand for construction sand and gravel in 1993 was expected to be about 940 million tons, a 2.5 percent increase compared with that of 1992. Gradual increases in demand for construction aggregates are anticipated after 1993 as well. The factors that stimulate demand in the construction sand and gravel industry are similar to those that affect the crushed stone industry (i.e., the Intermodal Surface Transportation Efficiency Act of 1991 and the recovery of the U.S. economy). Similarly, construction sand and gravel prices are not expected to rise significantly, except for the delivered prices. It is estimated that the demand for construction sand and gravel will reach 975 million tons in 1995. The projected increases will be influenced by construction activity, primarily in the public construction sector.

Dimension stone production for 1993 was estimated at 1.17 million tons, approximately the same as in 1992. The construction industry, a major consumer of stone and stone products, is expected to boost demand for stone and stone products. Increases in new residential construction should also boost demand for stone and stone products.

The domestic construction industry also provided an impetus for mineral demand in 1994. The construction industry is the largest domestic consumer of brick, clay, cement, sand and gravel, and stone. Expenditures for road construction and maintenance (which consume large quantities of asphalt, cement, crushed stone, and sand and gravel) continued at a high level in 1994 and are expected to remain strong in 1995 due to continued funding for mass transit projects. In addition, apartment building construction (a major end-use sector for brick clay, cement, sand and gravel, steel, and stone) rose sharply in 1994.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the non-fuel, non-metal mining industry, including the materials and equipment used, and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of waste outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available to supplement this document.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes may be produced in the process. This section also describes the potential fate (air, water, land) of these waste products.

III.A. Industrial Processes in the Non-Fuel, Non-Metal Mining Industry

Minerals extraction is broadly divided into three basic methods: open-pit or surface, underground, and solution mining. The mining method used depends on the particular mineral, the nature of the deposit, and the location of the deposit. Each method is discussed briefly below. For this industry, most mining is open-pit or surface mining.

Surface or open-pit mining requires extensive blasting, as well as rock, soil, and vegetation removal to reach mineral deposits. Waste rock, or overburden, is piled away from the mine. Benches are cut into the walls of the mine to provide access to progressively deeper ore, as upper-level ore is depleted. Ore is removed from the mine and transported to processing plants for concentration.

Exhibit 4
Flow Diagram for a Typical Sand and Gravel Operation

Source : California EPA and the National Stone Association, Aggregate Plants Compliance Assistance Program, September, 1993.

Underground mining involves extraction from beneath the surface at depths as great as 10,000 feet. This requires sinking shafts to reach the main body of deposits. "Drifts," or passages, are then cut from the shaft at various depths to access the ore, which is removed to the surface for processing. Waste rock may be either returned to the mine as fill or put in a disposal area.

Fluid or solution mining entails drilling into intact rock and using chemical solutions to dissolve lode deposits. During solution mining, the leaching solution (usually a dilute acid) penetrates the ore, dissolving soluble minerals. This pregnant leach solution is then retrieved for recovery at a solvent extraction/electrowinning plant.

Historically, the primary mining method has been underground mining. However, with the advent in recent decades of large earth moving equipment, less expensive energy sources, and improved extraction and beneficiation technologies, surface mining now prevails in most industry sectors. It usually costs less to mine a ton of rock from an open-pit mine than from an underground mine. Whether open-pit mining is ultimately less costly than underground mining is closely related to other factors such as stripping ratios, physical properties of the ore body, rates and productivity.

Minerals Extraction

The extraction of minerals from the earth often involves the use of mechanical means such as drilling. Some drill types include rock, diamond, water-jet, and jet flame. Rock and diamond drills involve the rotation of a pipe or rod tipped with a rolling gear-like bit; water-jet drills use a powerful jet of water to blast materials loose; jet flame drills use a high-velocity flame to create holes in hard rock. Other machines unique to mining include mechanical miners and specially adapted materials-handling equipment for use in underground and surface mining. Diesel engines are used for generating small quantities of electric power in remote areas and for transportation units.

Blasting is a method of mineral extraction involving the displacement of solid rock through the use of explosives. Blasting also fragments the deposit into sizes that require a minimum of secondary breakage, and that can be handled by loading and hauling equipment. The explosive charge (usually a mixture of ammonium nitrate and fuel oil) used in blasting must be strategically placed so as to break the solid material efficiently.

Extraction without the use of mechanical methods is also possible if the material surrounding the mine opening is not adequately supported. By removing underlying support, the rock caves into the opening left by the removed supports. If rock needs to be broken down further for transportation, secondary breakage may be required. This involves using drop-ball cranes on the oversized rock to further reduce its size.

Minerals Transportation

The excavation and loading of broken rock is normally performed by mechanical shovels and front-end loaders. The broken rock is either loaded into a haulage vehicle, such as a truck or railroad track-type car for transport to a processing plant, or directly into a primary crusher. At most quarries, large capacity haulage vehicles are used to transport broken rock from the quarry to the primary crusher. Pipelines have also been used successfully to transport many different minerals, such as limestone, phosphates, and sand fills: the dry material is first combined with water to form a slurry and is then pumped to its destination for dewatering. If sufficient dump room or storage capacity exists near the mine, a system of belt conveyors can handle material at high rates and relatively low cost, but only if proper feed control of a sized material allows a continuous, even flow that matches the system design. Other factors that determine the practicality and size of a conveyor system are the rate at which the material must be handled, the material's density and stickiness, the dusting or degradation on transfer, and the need for the system to handle more than one product.

Minerals Processing

Processing minerals after their extraction and transportation to the processing plant involves the use of crushers, grinders, and screens. This equipment is used to separate or scalp larger boulders from the finer rocks that do not need primary crushing, thus minimizing the load to the primary crusher. Following crushing, a variety of mechanical concentration techniques are used to concentrate the desired minerals. Techniques used for non-fuel, nonmetallic minerals include flotation, heavy media separation, and electromagnetic separation.

Flotation is a method of concentrating targeted minerals which uses the physical and chemical properties of the minerals along with process chemicals to separate desired minerals from remaining wastes. Typically, the mineral is entered into an acidic or basic bath of flotation agents. Depending on the type of mineral being concentrated, this bath may consist of such chemicals as sulfuric acid, chromium, phenols, zinc, ammonia, hydrochloric acid, and phosphoric acid. The wastes, including the spent process liquids, are discarded.

Heavy media separation utilizes mainly organic chemicals to separate minerals using the minerals' density differences. Electromagnetic separation uses a magnetic field to remove impurities from the target mineral.

Following are brief descriptions of processes used in mining major non-fuel, nonmetallic minerals.

Dimension Stone

Dimension stone refers to rock that is cut to a certain shape and size. It is commonly used as building material in the construction industry. Common types of dimension stone are limestone, granite, dolomite, sandstone, marble, and slate. Processing the stone begins with sawing the excavated rock into slabs using a rotating diamond or circular saw. Water is used to cool the saws and to remove particles. After the stone has been cut to the desired size, it is finished using natural and synthetic abrasives. Natural abrasives include iron oxide, silica, garnet, and diamond dust. Synthetic abrasives include silicon carbide, boron carbide, and fused alumina.

Crushed and Broken Stone, Including Riprap

Nearly all principal types of stone, including granite, diabase, limestone, sandstone, dolomite, and marble may be used as sources of commercial crushed stone. Stone that breaks in chunky, cubical fragments and is free of surface alteration from weathering is preferred for crushed stone. Such stone should also be free of impurities such as opalescent quartz, which may react with lime in cement and cause disintegration of the concrete in which the stone may be used. Most crushed and broken stone is mined from open quarries; however, in many areas, factors favoring large-scale production by underground mining are becoming more frequent and more prominent.

Surface mining equipment varies with the kind of stone mined, the production capacity needed, the size and shape of the deposit, estimated life of the operation, location of the deposit with respect to urban centers, and other important factors. Ordinarily, drilling is done with tricone rotary drills, long-hole percussion drills, and churn drills. Blasting in smaller operations may still be done with dynamite, but in most medium- to large-size operations, ammonium nitrate fuel oil mixtures (AN-FO), which are much lower in cost, are used.

Other processing activities include conveying, screening, secondary and tertiary crushing, and sizing. Screening is the single most important part of the processing cycle of crushed stone particles. A wide variety of screen types exists, and their selection is a function of the material processed as well as the final product required. Inclined vibratory screens are most commonly used in stationary installations, while horizontal screens are used extensively in portable plants. For screening large sizes of crushed stone, grizzly bars, rod decks, and heavy punched steel or plastic plates are used; for smaller sizes, woven wire, welded wire cloth, rubber, or plastic screens are used. Stone washing is something performed, which consists of processing the crushed stone across sizing screens where it is saturated with water, in order to remove unwanted material.

Underground operations are becoming more common, especially for limestone mining in the central and eastern parts of the United States, as the advantages of such operations are increasingly recognized by the producers. By operating underground, a variety of problems usually connected with surface mining such as environmental impacts and community acceptance are significantly reduced. Underground room-and-pillar mines can be operated on a year-round basis, do not require extensive removal of overburden, and produce a minimum of environmental disturbance.

Of the total crushed stone produced in 1993, about 71 percent was limestone and dolomite; 15 percent granite; and eight percent traprock. The remaining six consisted of sandstone and quartzite, miscellaneous stone, calcareous marl, shell, marble, volcanic cinder and scoria, and slate. Limestone is used in the manufacture of products such as glass, paper, paint, sugar, and cement; of the 1.2 billion tons of crushed stone produced in 1993, approximately 81 percent was used as construction aggregates, mostly for highway and road construction and maintenance; 15 percent for chemical and metallurgical uses including cement and lime manufacture; three percent for agricultural purposes; and one percent for miscellaneous uses and products.

Sand and Gravel

Sand and gravel are the unconsolidated granular materials resulting from the natural disintegration of rock or stone. Sand and gravel deposits are commonly found adjacent to or in river courses or in areas with glaciated or weathered rock. Such deposits often contain the fine alluvial silt that is the primary source of process and fugitive dust from sand and gravel operations.

There are two main types of sand and gravel. Construction sand and gravel are used mainly in concrete, road-base, asphaltic concrete aggregates, and construction fill. Generally, the physical characteristics of construction sand and gravel and their proximity to construction sites is more important than their chemical characteristics. Industrial sand and gravel are used mainly in manufacturing glass, ceramics, and chemicals. The chemical and physical characteristics of industrial sand and gravel are very important to their end uses, and are therefore subject to stricter chemical and physical characterization than construction sand and gravel.

Loose sand and gravel deposits are usually mined without the necessity of drilling and blasting. On rare occasions, blasting with light charges is used to loosen deposits.

Extraction and mining is done by any number of methods, depending on whether the deposit is above or below the water table. Where sand and gravel are above water, extraction is done by power shovels, drag line scrapers, and/or by highly mobile, rubber-tired front-end loaders.

When the sand and gravel deposit is consolidated to the point where digging with a front-end loader or power shovel is too difficult, a bulldozer equipped with a ripper is used to loosen the material. A ripper consists of a large tooth (or series of teeth) which is attached to the rear of the bulldozer and pulled through the material as the bulldozer moves forward. Materials mined below water, in rivers, estuaries, lakes, and oceans must be removed with specialized equipment. This equipment includes dredges, draglines and floating cranes.

Clay, Ceramic, and Refractory Minerals

Common types of clay, ceramic, and refractory minerals include kaolin, ball clay, bentonite, fuller's earth, fire clay, common clay, and shale. Processing of minerals in this category usually entails a combination of crushing, grinding, screening, and shredding to reduce particle size. For kaolin and ball clay, wet and dry processing methods are used. The wet process employs liquid chemical dispersants (phosphates, phosphoric acid, hydroxides) and water to remove impurities. A clay slurry is formed and is made either acidic or basic using sulfuric acid or alum. The slurry is then chemically leached using a reducing agent such as zinc hydrosulfide, ozone, or peroxide to remove unwanted iron and titanium ions. The slurry is dried to remove water and unwanted chemical compounds such as phosphates, phosphoric acids, silicates, iron, and zinc. Clay beads are then formed that are pulverized and calcined (heat treated).

Chemical and Fertilizer Minerals

These minerals include potash and phosphate rock. Potash, a term that describes minerals containing potassium compounds, is used in fertilizers. Processing potash involves mixing crushed potash ore with a brine which is saturated with potassium chloride and sodium chloride. Froth flotation, crystallization, or heavy media separation methods are then used to recover potassium-bearing compounds from the saturated solution.

Processing phosphate rock usually consists of sizing and flotation. Crude ore is pumped and slurried in wells and is transported to a washing plant for sizing. Fine concentrate is sent to flotation, where various flotation methods are used on the concentrate. Typical flotation reagents used include sulfuric acid, which is used in product scrubbing, and soda ash. Additional flotation reagents include fatty acids and amines. Phosphate rock is used mainly in fertilizer manufacturing. Phosphate rock mining involves the movement of huge volumes of soil and other materials in overburden. Phosphate rock preparation involves beneficiation to remove impurities, drying to remove moisture, and grinding to improve reactivity.

Usually, direct-fired rotary kilns are used to dry phosphate rock.

Non-fuel, Nonmetallic Minerals Services

This industry code includes facilities which specialize in specific areas of mining operations and which perform services on a contract basis. Specialty areas include exploration and mine development. From a process and chemical use standpoint, activities in this SIC code are similar to other activities conducted in other SIC codes. During the exploration and characterization of a mineral deposit, samples of rock must be collected and analyzed. Drill-based sampling methods are routinely used to characterize a mineral deposit at different depths. These methods include rotary, percussion, auger, and diamond drilling. Diamond drilling will extract a cylindrical core of material, while the former three methods will extract fragmented material. All share the objective of collecting ore material for analysis.

Miscellaneous Non-fuel, Nonmetallic Minerals

Minerals included in this category include lightweight aggregates (pumice, vermiculite), asphaltic minerals (gilsonite, wurtzilite), natural abrasives (millstone, diatomite), gemstones (jade, sapphire), and other minerals, such as asbestos and gypsum. Processing these minerals usually involves crushing, grinding, screening, flotation, heavy media separation, and drying methods similar to those used for other minerals. As in processing other non-fuel, nonmetallic minerals, wet methods are more chemically intensive than dry methods due to the use of various flotation agents to refine the mineral.

III.B. Mining Process Waste Outputs

III.B.1. Process-Specific Wastes

Minerals Extraction

The extraction of minerals requires the removal and disposal of overburden, a layer of soil, vegetation, and rock. Waste rock generated in both surface and underground operations is removed and usually disposed of in impoundment areas or is used to backfill mines. Wastewater is generated from the use of water to suppress dust, wash away waste from the working zone, and cool excavation machinery such as drills. Dusts are generated from the cutting, drilling, sawing, and blasting required to remove the rock. Explosives used in excavation contain mixtures of ammonium nitrate and fuel oil. Hydrocarbons used in machinery as lubricants and fuels can be sources of pollution.

Minerals Processing

Wastes generated from minerals processing include dusts, solid matter, and water effluents. Crushing and screening operations performed to reduce the size of particles are also sources of dust emissions and solid waste. This waste may contain minerals that react with air and water to produce metal ions capable of contaminating water resources such as rivers, streams, and groundwater.

Processes used to remove mineral impurities can be a major source of water contamination. Flotation, a wet method used to refine certain non-fuel, nonmetallic minerals (sand and gravel, kaolin, potash, phosphate rock) is a potential source of water pollution due to the chemicals used to separate impurities from the mineral. Flotation involves placing minerals in an acidic or basic bath of chemicals where pH modifiers such as sulfuric acid, ammonia, and hydrofluoric acid are used to control pH levels in order to separate impurities from the target mineral. Additional materials may be added to the flotation bath to assist in removing impurities, including frothers, conditioning agents, sulfonated oils, and heavy alcohol.

Exhibit 5 summarizes the types of wastes produced at various points in the non-fuel, nonmetal mining industry.

Exhibit 5
Process Waste Materials

Primary	Subprocesses	Air Emissions	Process Waste Water	Other Waste Generated
Minerals Extraction	Drilling, blasting, secondary breakage	Particulates, exhaust from machinery	Surface runoff, groundwater seepage	Overburden (soil, rock)
Minerals Transportation	Loading, conveying, off-road haulage, unloading	Particulates, exhaust from vehicles and machinery	Water for transportation of ore to process plant	
Minerals Processing	Crushing, grinding, screening, washing, drying, calcining, floating	Particulates	Transport water, ore and product wash water, dust suppression water, classification water, heavy media separation water, flotation water, solution water, air emissions control equipment water, equipment, and floor wash down water	Tailings

III.B.2. Mineral-Specific Pollutants

Sand and Gravel

Particulate matter is emitted from sand and gravel operations and is made up principally of inert crustal material (e.g., soil and rock particles). Dust emissions in the form of fugitive dust occur during removal of overburden and sand and gravel from the deposit; from wind-blown dust from storage piles; from traffic on haul roads; from open conveyors exposed to the wind; during material dumping from trucks, front-end loaders, and conveyors; from screening; and from transfer points in conveyor systems. If wet screening is used to produce a washed gravel product, negligible amounts of dust are produced, but effluent water must be clarified by settling before reuse or discharge. The amount of moisture a deposit contains affects the amount of dust emissions that occur. If the deposit is dry and the material and overburden have a high silt content, dust emissions may be significant. If the deposit is wet or is removed by dredging, dust emissions tend to be negligible as long as a high moisture content is maintained in the material.

Methods of controlling dust emissions from sand and gravel operations include using water sprays to keep materials and roads wet, limiting the drop heights of materials, covering trucks and conveyors, using enclosures or hooding material at transfer points and screening operations, and exhausting air from these points to air pollution control systems.

Stone

The source of crushed stone is usually a deposit of relatively solid rock such as limestone, dolomite, trap rock, granite or sandstone. Dust emissions occur from many operations in stone quarrying and processing. Dust is released when rock and crushed stone products are loosened by drilling or blasting them from their deposit beds. Dust is also released when the loosened rock is loaded into trucks by power shovels or front-end loaders. Transporting the quarried material to the processing plant generates dust from the rock inside the truck and from the road. Sources of dust at the processing plant include the dumping of rock into primary crushers; primary, secondary, and tertiary crushing; screening; transferring rock by belt conveyor; loading rock onto storage piles from conveyors; and wind blowing dust from storage piles and open conveyors.

Particulate matter produced during stone quarrying and processing is usually of relatively large particle size. The chemical composition of the dust tends to be homogeneous since its ancestry is the rock formation from which the rock deposit was taken.

Air pollution control techniques for stone quarrying and processing plants include wetting the material and/or surfaces; covering open operations to prevent dust entrainment by the wind; reducing the drop height of dusty material; and using hooding, industrial ventilation systems, and dust collectors (e.g., baghouses) on dusty processes amenable to enclosure. Dust recovered from air pollution control systems is often a valuable product in road building and other construction operations.

Phosphate Rock

Although there are no significant emissions from phosphate rock beneficiation plants, emissions in the form of fine rock dust may be expected from drying and grinding operations. Phosphate rock grinders can be a considerable source of particulates. Because of the extremely fine particle size, baghouse collectors are normally used to reduce emissions. Effluents produced in the mining and beneficiation of phosphate rock are contained in the water suspensions leaving the washer plant. These suspensions are the phosphatic clays and sand tailings. The major effluent is that of the phosphatic clays which contain a suspension of clays and very fine solids. These phosphatic clays are impounded in slime ponds to allow settling and clarification to occur. Clear water is returned from the ponds to the beneficiation plant. When phosphate rock is calcined, fluoride is produced. The fluoride produced is scrubbed with water or dilute hydrofluoric acid.

Because proposed mining activities may also impact aquatic sources, vegetation and wildlife, EPA suggests the following potential mitigation measures for use at mine sites:

Exhibit 6
Ecosystem Mitigation Measures

- Employ sediment retention structures to minimize amount of sediment migrating off-site
- Employ spill prevention and control plans to minimize discharge of toxic/hazardous materials into water bodies
- Site roads, facilities, and structures to minimize extent of physical disturbance
- Avoid construction or new disturbance during critical life stages
- Minimize use of fences or other such obstacles in big game migration corridors; if fences are necessary, use tunnels, gates, or ramps to allow passage of these animals
- Use "raptor proof" designs on power poles to prevent electrocution of raptors
- Use buses to transport employees to and from mine from outer parking areas to minimize animals killed on mine-related roadways
- Limit impacts from habitat fragmentation, minimize number of access roads, and close and restore roads no longer in use
- Prohibit use of firearms on site to minimize poaching.

Source: US EPA, OSW Technical Document/Background for NEPA Reviewers: Non-Coal Mining Operations, 1994.